Monolithic Amorphous Silicon Modules on Continuous Polymer Substrates

Highlights

- Reduced a-Si module-manufacturing costs by 42%
- Increased production capacity by a factor of 4
- Developed new method of printing registration using active screen steering for interconnect printing step, which increased throughput by factor of 6
- Improved printing registration reproducibility from 100 to 10 micrometers
- Developed a roll-based lamination process that increases per-machine lamination throughput from 102 to 2402 feet per hour

This Iowa Thin Film Technologies, project is part of the 1995 solicitation of PVMaT—a cost-shared partnership between the U.S. Department of Energy and the nation's PV industry to improve the worldwide competitiveness of U.S. commercial PV manufacturing.

PVMaT Fact Sheet

Photovoltaic Manufacturing Technology

Iowa Thin Film Technologies, Inc.

Goal

Iowa Thin Film Technologies' (ITFT) goal under the 1995 PVMaT solicitation was to reduce manufacturing costs while increasing production of the company's manufacturing process. ITFT's specific objectives were to:

- reduce by 68% the costs of manufacturing monolithic a-Si modules
- increase overall module performance
- provide the groundwork for expanding production capacity
- increase the throughput of the metallization, a-Si deposition, laser-scribing, and screen-printing processes.

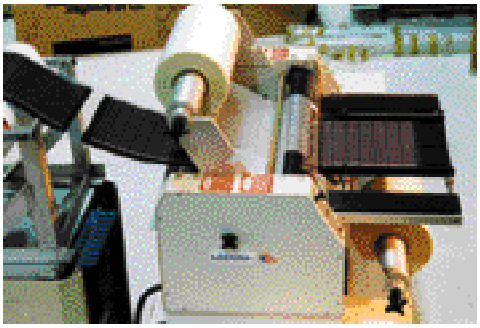
Background

ITFT manufactures a lightweight, flexible, a-Si solar module for electrical power generation. With the overall goal of developing the most cost-effective PV manufacturing process possible, ITFT's solar modules are made using a roll-to-roll manufacturing process, with continuous deposition and monolithic integration. A plastic substrate (polymer web) is used that is 2 mils (0.05 mm) thick, 13 inches (33 cm) wide, and up to 2400 ft (732 meters) long. ITFT's automated, module manufacturing equipment can custom manufacture solar modules of specified voltage and current for a given module area, using monolithic creation and interconnection of solar cells on the substrate.

Technical Approach

ITFT has numerous activities for this 3-year project, broken down by year:

First-year activities—replace the TiN layer with a reflection-enhancing, less-absorbing ZnO layer; implement a registration system for aligning the web onto the printer platen; optimize the laser-beam scribe speed; and develop new insulating ink printing and roll-based laminating processes for the production line.



Frank R. Jeffrey, ITFT/PIX06416

A roll-to-roll encapsulant laminator turning out thin film.

Second-year activities—increase throughput of metallization, a-Si deposition, laser-scribing, and printer processes; implement baffles for isolating metal deposition regions; investigate ZnO deposition rates; develop new machine-control programs; integrate a water-based insulating ink into the patterning process; and automate the final process steps of busbar attachment and web cutting.

Third-year activities—increase throughput of metallization deposition systems; determine deposition parameters for each layer to produce the full metallization stack at a single web speed; increase throughput in the roll-to-roll ZnO deposition system; study alternate feedstocks for Zn and O in the ZnO growth process; study alternative processes for scribing and printer steps; study cost-reducing alternatives to laser operations; study alternative scribing methods, including blade, electrochemical, and ultrasonic cutting tips; study alternative methods of welding shunts in cell-interconnects; reduce the cost of the polymer substrate; and establish a roll-based laminating process and decrease module-assembly labor costs.

Results

Significant progress has been made in decreasing cost and increasing throughput of the ITFT manufacturing process. A 49% reduction in manufacturing cost to date is attributed to increased automation, selection of a new encapsulant, and improved deposition and patterning processes.

Designed Automated Busbar and Sheeting Machine

The base system for busbar attachment is configured on a platen that has taping heads to place the conductive bus on the web. The taping heads travel across the web, placing the conductive busbar. A vacuum hold-down plate prevents the web from moving while the tape is applied. At the end of the stroke, the heads cut the tape and are raised off of the web to allow the heads to return to the beginning of the stroke without touching the web. After placing the tape, the web advances to the next busbar placement location. As the web advances, the taping heads return to their original position, and the process is repeated.

The sheeting/die cutting system uses the same base system and follows a process similar to the busbar system.The web is aligned relative to the press, and once the web is aligned, the press cycles to cut the PV material according to specification. Optical sensors verify that the PV modules have been removed from the die before another stroke of the press. The press proceeds to the top of its stroke, then the web is air-kissed off the die bottom, where it is advanced to the next frame.

Tested Potential Laminator Layer Materials In-house

A group of encapsulants were first tested for salt-water corrosion, 80°C soak, and thermal cycling (-40° to 80°C).The three best candidates of laminated 1-ft^2 single-junction a-Si modules were then sent to the National Renewable Energy Laboratory for UV exposure testing as specified in IEEE Standard 1262.

The three modules were exposed for 35.1 days under UV irradiance of 17.8 W/m^2, for a total exposure of 54 MJ/m^2—or an approximate lifetime UV exposure of 10 years under normal irradiance. Losses in maximum power were mainly due to Staebler-Wronski light-induced degradation, with the nylon/silicone encapsulant showing greatest overall losses due to yellowing of the non-UV-stabilized nylon film.

ITFT then measured optical transmission on these modules. In the two polyester/ polyethylene-encapsulated modules, the greatest losses occurred between 350 and 450 nm; these losses of 13%–16% are relatively negligible. There was an increase in the percentage of light transmitted from 550 nm to the end of the visible-light spectrum at 750 nm.The nylon/silicone encapsulant showed the greatest losses in light transmittance throughout the entire visible spectrum, in part, because the nylon film was not UV-stabilized. Most losses again occurred between 350 and 500 nm, in the lower third of the visible-light spectrum.

These results indicate that the polyester/ polyethylene encapsulants are reasonable for a product having a medium lifetime of up to 10 years. Further long-term testing will be done to ensure the durability of these encapsulants.

Brought New Tandem Deposition System On Line

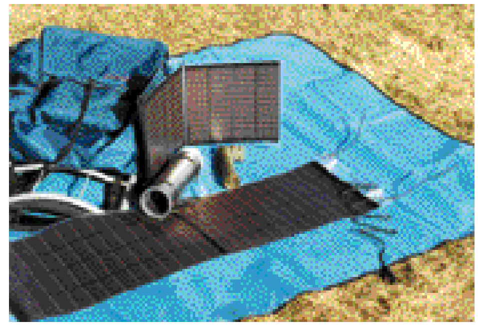
A new single-pass tandem deposition system was brought onto the production line. The deposition system was calibrated before fabricating the initial devices. The device voltages were lower than anticipated, but the machine is being modified to alleviate this situation.

Company Profile

Iowa Thin Film Technologies, Inc., is located in Ames, Iowa, and is associated with Iowa State University's Microelectronics Research Center.

The company was founded in 1988 by Dr. Frank Jeffrey and Dr. Derrick Grimmer building on research performed by Dr. Jeffrey at 3M.

ITFT designs, manufactures, and sells lightweight, flexible solar cells that convert light into electric power for non-grid electrical applications.



Frank R. Jeffrey, ITFT/PIX06422

ITFT flexible lightweight power modules can be used for equipment such as radios and for battery charging.

References

Jeffrey, F.R.; Grimmer,D.P.; Brayman, S.; Scandrett, B.;Thomas, M.; Martens, S.A.; Chen, W.; Noak, M. "PVMaT Improvements in Monolithic a-Si Modules on Continuous Polymer Substrates," in *AIP Conference Proceedings 394, 14th NREL Photovoltaics Program Review*, Lakewood, Colorado, 1997, pp. 451–461.

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